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How reliable is the Peak-over-threshold extreme wind assessment method?

On the Peak-Over-Threshold (POT) Extreme Wind estimation as applied at DTU Wind Energy - Recently implemented in WAsP Engineering

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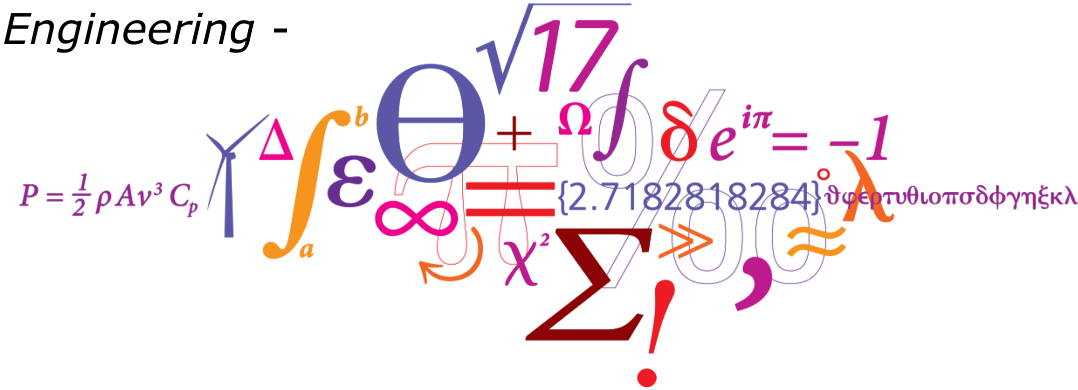
- *Recently implemented in WAsP Engineering* -



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Extreme Wind Prediction - background

- For wind turbine selection, typically the 50-year extreme wind is required

- Annual Max. method [1]: Based on Ann.max wind speeds distribution.
  - Requires typically 10Y+ of data
  - Gumbel double-log distribution is used for extrapolating to 50 Y.

- POT (Peak Over Threshold) [2]: Based on individual storm winds distribution
  - Potentially, shorter time series should be usable
  - 1000$ Q: How short time series could be used without excessive uncertainty?

1) Gumbel, E.J.: Statistics of Extremes. Columbia University Press (1958)

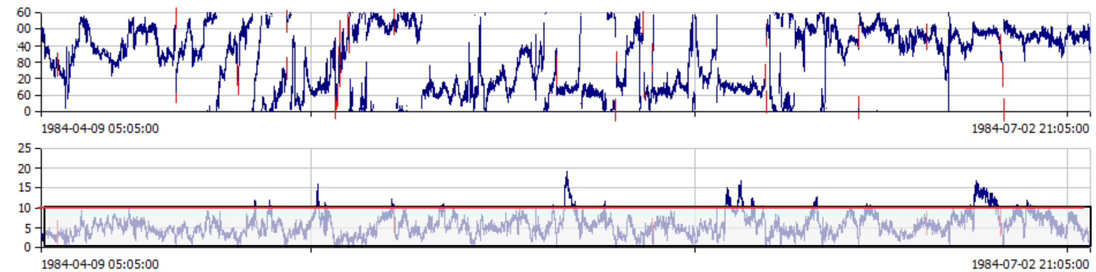
2) Abild J. Application of the wind atlas method to extremes of wind climatology.
Technical Report Risoe-R-722(EN), Risø National Laboratory, Roskilde, Denmark (1994).

POT - Basics

- Based on Peak-wind speeds of individual storms
- Considers the exceedance rate R over a threshold (how many per year?)
  - Use $\mathrm{Min}(\ U_{Ann.Max}\ )$ as reference threshold
- How does R decrease with increasing threshold?

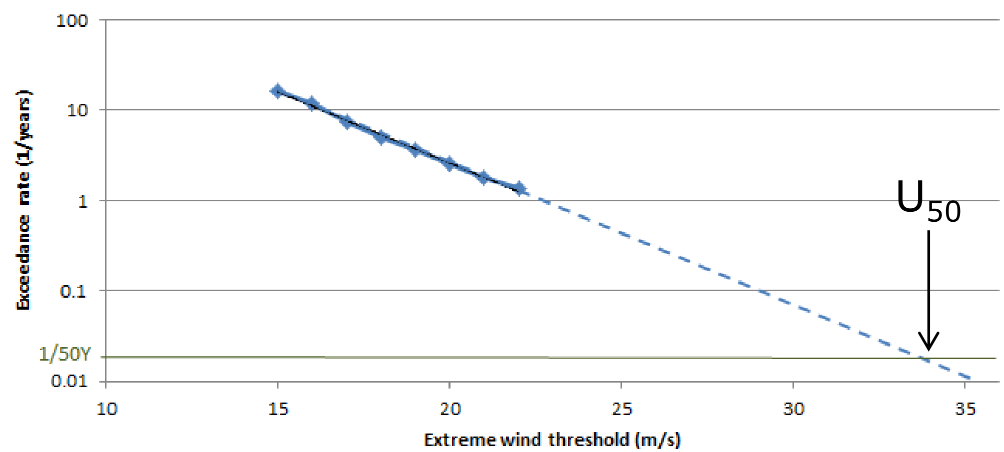
Storms discriminated by

- Lower speed threshold
- Max. storm duration
- Min. storm separation



Exceedance rate R

- Exponential decay
- Extrapolation to a certain return-time to get e.g. U_{50}
- Quality control from statistical test (Poisson statistics)



POT – Demonstration – 4 test cases

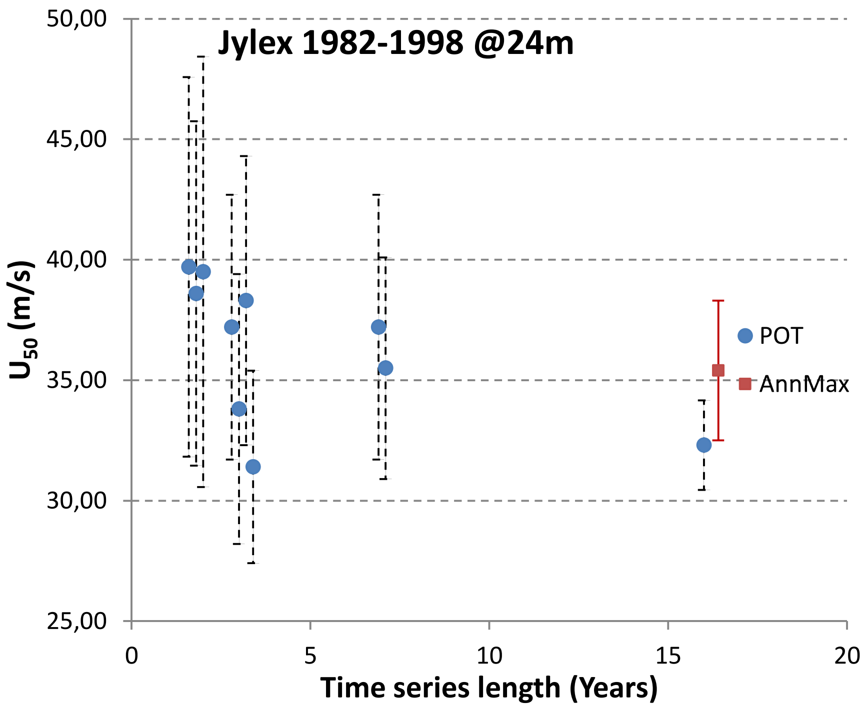
- Indication of the reliability of the POT-method from 4 test cases

Name	Location	Type	Height	Time series length
Jylex	Denmark	Inland	24.0 m	16 years
Sprogoe	Denmark	Off-shore	70.0 m	22 years
Abu Darag	Egypt/Red Sea	Subtropical high	24.5 m	12 years
Bloemenfontein	South Africa	Continental	10.0 m	17 years

  - Various time series lengths (full length; 6, 7 or 8y; 3y; 2y)
  - Compared to ann.max method (full time series length)

POT – Demonstration – 4 test cases (A)

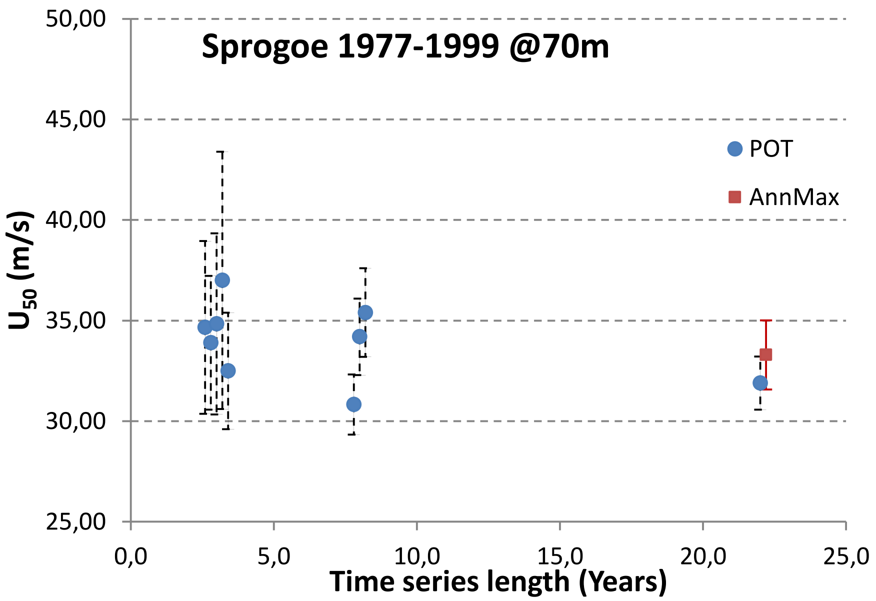
- Indication of the reliability of the POT-method from 4 test cases
  - Uncertainties deduced from Poisson-deduced statistics [3)]



3) Larsén, X.G., Uncertainties of the 50 year wind from short time series using generalized extreme value distribution. Wind Energ. **18** pp59 (2015).

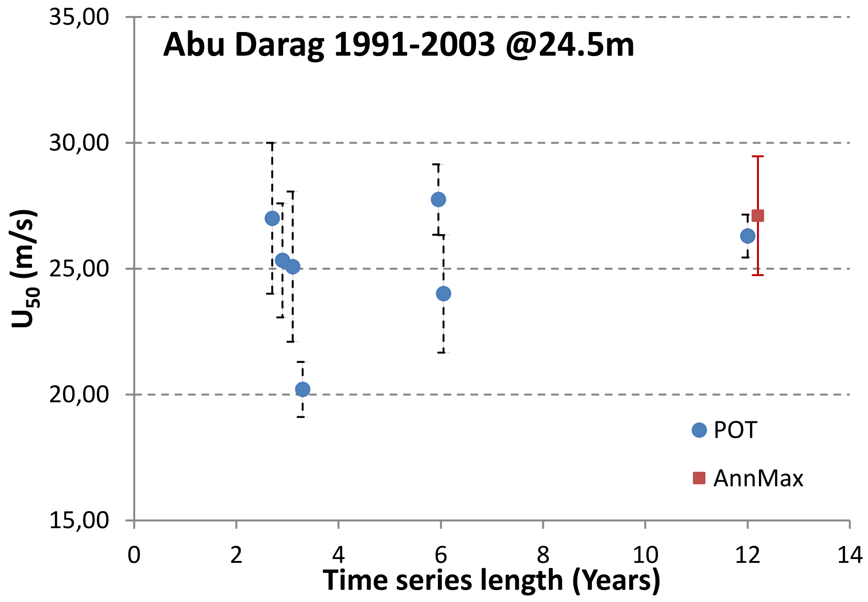
POT – Demonstration – 4 test cases (B)

- Indication of the reliability of the POT-method from 4 test cases



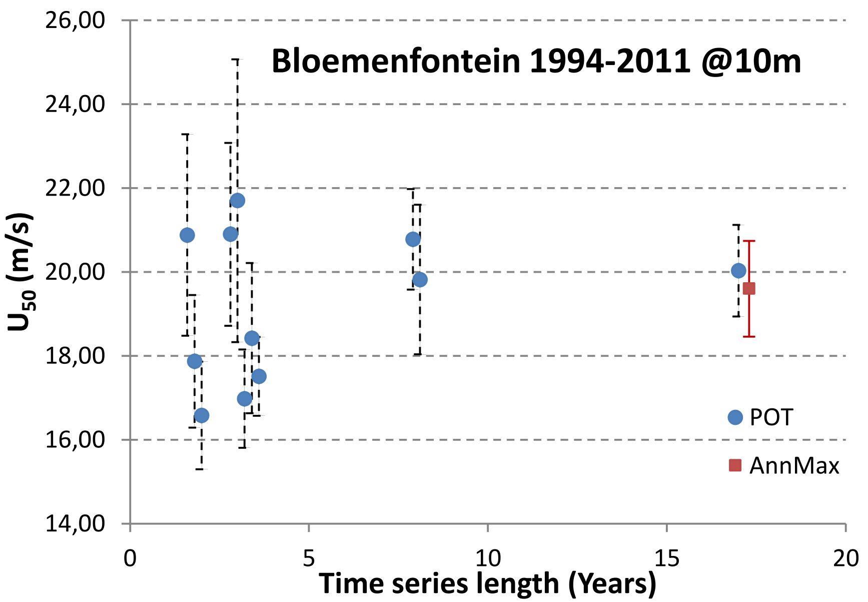
POT – Demonstration – 4 test cases (C)

- Indication of the reliability of the POT-method from 4 test cases



POT – Demonstration – 4 test cases (D)

- Indication of the reliability of the POT-method from 4 test cases



POT and Terrain effects

Beware!

- POT may be influenced by terrain effects when predicting 50-year winds at turbine sites by high-wind data from a met-tower:
  - A certain measured “storm wind-peak” may not be a storm wind peak when transformed from mast site to a “predicted” wind turbine site
  - What seems to be a low or moderate wind at mast site may become a “storm wind” when transformed to a predicted wind turbine site.
- Special measures must be exercised to ensure that all relevant high-wind data are transformed to wind turbine sites for the POT-extreme wind estimation there.

Short term data – why do predictions fail? What to do about it?

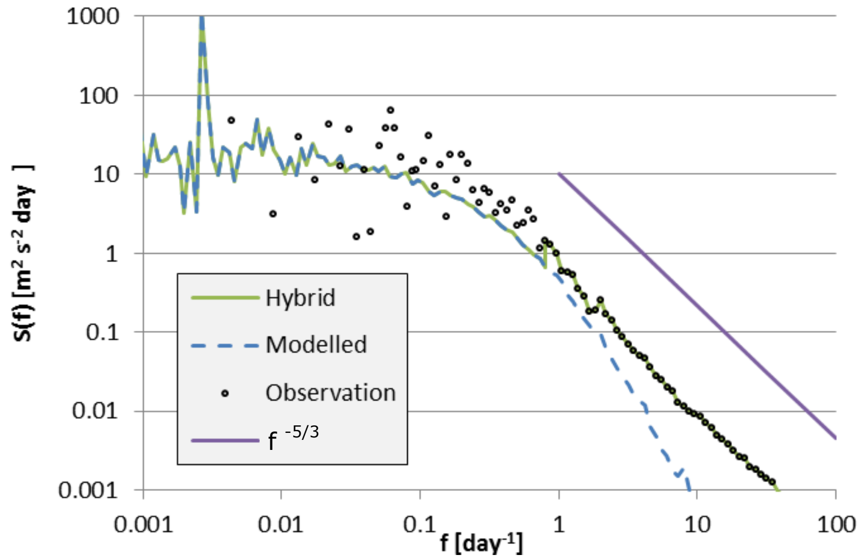
- Short term data: 1 or a few years
  - Normally represents short-term fluctuations quite well: 10 min. recording interval or better assumed.

- Long term year-to-year variance CANNOT be represented
  - E.g., for a single year: is this a high, average or low year ???
  - Unless you combine with a long term reference data set

- Long-term model wind data from reanalysis data + Mesoscale-model may be used
  - Model data (1h) have an insufficient representation of the dynamics at relatively high frequency
  - Impact of the high frequency dynamics must be corrected for

Model-data high frequency dynamics issue How to handle this?

- Power spectrum
  - Model data 32Y
  - Measured data 1Y
  - Both generalized (*terrain cleansed*)
- Hybrid spectrum
  - Low freq.: model l.t. data
  - High freq.: meas. s.t. data



- Relation between power spectrum and predicted T_0-extreme wind

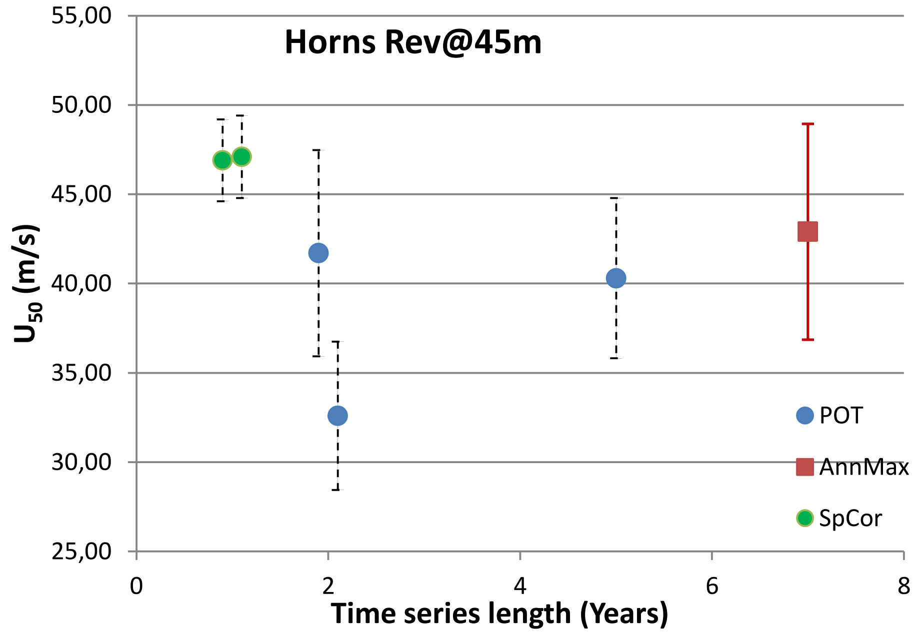
$$\overline{U}_{\max}(T_0) = \overline{U} + \sigma \sqrt{2\ln\left(\frac{1}{2\pi}\sqrt{\frac{m_2}{m_0}}T_0\right)}, \sigma = \sqrt{m_0}$$

- Spectral correction procedure[4]:
  - Use model- and hybrid spectra + U_{max} equation to correct U_{max} for all years of l.t. data series.
  - Use set of corrected U_{max} in combination with Ann.max method

[4] Larsén, X.G. et al.: Recipes for correcting the Impact of Effective Mesoscale Resolution on the Estimation of Extreme Wind., J.App.Met. and Clim. **51,** pp521(2102).

AnnMax – POT - Spectral Correction

- Spectral correction applied to off-shore data: Horns Rev@45m
  - Involves *terrain effects cleansing* and *terrain effects inclusion*
  - Compared to POT and Annual Max



Spectral correction:

Model data: 32 years (1979-2011)
CFSR-ReAn. Data (NCEP)

Obs.data: 1 year (2001/2005-06)

- The "Spectral correction" needs further validation

Conclusion

- POT compares well with the annual Max. method
  - Same time series length: same result as Ann.Max. – but with somewhat lower uncertainty
  - Short time series:
    - Agrees largely with l.t. Ann.Max. – but with higher uncertainty, as expected
    - No or slightly negative bias
    - Cannot take long-term variability into account – unless long term reference data are somehow included (trivial)

- Spectral correction is a promising method to combine a short measured time series with long-term wind data derived from re-analysis data set by mesoscale models
  - Being validated at DTU Wind Energy against a number of cases
    - **for implementation in WAsP Engineering**.

Acknowledgements

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Egyptian NREA & DTU Wind Energy *(former Risoe)*
- Bloemenfontein: South African Weather Service

Spectral correction – work flow